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NAVIGATION, A. D. 1594.

BY LIEUTENANT COMMANDER ALLAN D. BROWN, U. S. N.

We who live in this latter half of the nineteenth century, and are furnished with such excellent means of navigating the trackless ocean that we are able to appoint a rendezvous for vessels in a given latitude and longitude, with the certainty of there meeting our fellow navigators, are apt to forget under what difficulties our predecessors labored less than three centuries ago.

It is my design to call the attention of the Institute briefly, to the state of the Art of Navigation at the close of the sixteenth century. For my ability to do this and to thus take a hasty glance at the condition of this branch of maritime knowledge at that day, I am indebted to a rare work which has recently been placed in the Library of the Naval Academy, through the kindness of Lieutenant Colonel JAMES H. JONES, U. S. Marine Corps. This volume bears upon its title page the following:

"M. BLUNDEVILE.

His Exercises, containing six Treatises, the titles whereof are set down in the next printed page, which Treatises are very necessary to be learned by all young gentlemen that have not been exercised in such discipline and yet are desirous to have knowledge as well in *Cosmography, Astronomy* and *Geography* as also in the *Art of Navigation*, in which Art it

is impossible to profit without the help of these, or of such like instructions.

To the furtherance of which

ART OF NAVIGATION

the said M. BLUNDEVILE specially wrote the said Treatises and of mere good will doth dedicate the same to all the young gentlemen of this realm.

LONDON.

Printed by John Windet, dwelling at the sign of the cross keys, near Paul's wharf and are there to be sold.

1594."

I have here as in all other cases of quotations modernized the spelling.

The book is arranged somewhat like our modern Epitome of Bowditch, containing treatises upon Arithmetic, Cosmography and the use of the globes and astrolabe.

In looking over the Arithmetic which, as M. Blundevile is careful to inform us, was written "for a virtuous gentlewoman and his very dear friend Elizabeth Bacon," we are at once struck with the absence of all mention of Decimal Fractions: but we do find a very elaborate description of Astronomical Fractions and many rules for the different operations to be performed upon them; these fractions, so called, were the arcs of degrees, minutes and seconds according to the sexagesimal system. We also find methods for the extraction of the square and cube roots of any number, with the following practical application of the square root. "The knowledge of finding out the square root of any number is very necessary for a Sergeant Major in the field, that he may the more readily set and arrange his squadrons of battle:" thus showing that even at that day some knowledge of Mathematics was by no means deemed amiss, in him

"Who'd set a squadron in the field."

Next follows a table of natural sines, tangents and secants with appropriate directions for taking out the function of any given arc, together with several applications of the uses to which these functions serve: one of the most notable of these is the finding of the distance (great circle) between two places whose latitudes and longitudes are given: this was of course simply the solution of a spherical triangle, but it was done in rather a roundabout manner. These tables were constructed by MONTE REGIO, and are credited to him by our author. Among the other uses for them, were the ascertaining of the sun's right ascension and declination having given his place in the Ecliptic, the

computation of the sun's Meridian altitude, of the time of his rising and setting and the solution of various other astronomical problems, into none of which however does the question of Equation of Time enter. The table of secants is further designated as the *Beneficial Table:* and that of tangents as the *Fruitful Table.*

Having thus given a brief glance at these first Mathematical principles, of which, by the way, nowhere does the author attempt the slightest explanation, our attention is next directed to the *Nautical Astronomy* or, as it is here called, *Cosmography.* This treatise has for its motto these words, which, as time goes on and astronomical research extends its domain, are found to be as true now as when first uttered by the Psalmist three thousand years ago, "The heavens declare the glory of God, and the firmanent showeth His handiwork." This is, perhaps, the most interesting portion of this quaint work, for we are here brought face to face with opinions and theories which we have been accustomed to consider as belonging to a time anterior to the date of the publication of this book.

"The world is round" says the author, "by these reasons: first by comparison, for the likeness it hath to God's mind; secondly, by aptness, as well of moving as of containing; for if it were not round of shape, it should not be so apt to turn about as it continually doth, nor to contain so much as it doth, for the round figure is of the greatest capacity." And this round world "turneth like a cart wheel about a right imaginative line through the Poles, called the Axletree of the Earth." "The world is divided into two essential parts, the celestial part and the elemental part. The celestial part contains the eleven heavens or spheres, which in ascending orderly upward from the elements be these; first, the sphere of the Moon; second, the sphere of Mercury; third, the sphere of Venus; fourth, the sphere of the Sun; fifth, the sphere of Mars; sixth, the sphere of Jupiter; seventh, the sphere of Saturn; eighth, the sphere of the fixed stars commonly called the firmament; ninth, the second movable or crystal heaven; tenth, the first movable; and eleventh, the Empyreal heaven, where God and His angels do dwell. The elemental part contains the element of fire, which is next to the sphere of the Moon, and next to that, more downward, is the element of the air, and next to that is the earth, which is lowest of all." Accompanying this description is a plate with fourteen concentric circles to represent these several spheres, the earth being at the centre of revolution. This was the Ptolemaic theory which had held undisputed sway for centuries: and although Copernicus had written

his treatise "*de Revolutionibus*" half a century before, his theory had not yet overthrown the more ancient one. Blundevile says in this connection; "Copernicus affirmed that the earth was movable, by way of supposition, *and not that he thought so indeed*: who affirmed that the earth turneth round and that the sun standeth still in the midst of the heavens; by help of which false supposition he hath made truer demonstrations of the motions and revolutions of the celestial spheres than ever were made before. But Ptolemy, Aristotle and all other old writers do affirm the Earth to be the center of the world, which I think few or none doubt thereof." The text next proceeds with a description of these several spheres, the eleventh or empyreal heaven being immovable: the tenth moves about the center from East to West in twenty-four hours, carrying all the others with it; while the ninth has its own proper motion as well, in a reverse direction, completing an entire revolution in thirty-six thousand years, at which time all things should be according to Plato, as they were at the beginning of the revolution; this ninth sphere also contains "the waters that be above the firmament." It is quite evident that the so called conflict between science and religion had even then begun, for the student's attention is called to the fact that "the natural philosophers allow no water to dwell above the heavens:" to which the reply is made, "That is true, yet, notwithstanding, if the holy scriptures manifestly affirm that there be waters above the firmament, it behooveth a Christian man to believe it; but question perhaps may be moved what manner of waters they are that are above the firmament, whether they be such as breed rain, or whether they are only to be referred to the crystal heaven to assuage its heat, which otherwise, owing to its swift moving, would set all the heavens on fire." A note opposite this paragraph, in faded ink and in a quaint handwriting, has these words "not very good." The eighth heaven is described as containing the fixed stars, so called because "they are fastened in this heaven like knots in a knotty board:" this had the motion from East to West in twenty-four hours, common to all the remaining heavens, but it also had the motion of the ninth heaven in the opposite direction; its own proper motion was a tilting one, causing the precession of the equinoxes. The heavens of the planets, sun and moon are then noticed and the term of the revolution of each from West to East given: the same period of three hundred and sixty-five days being assigned to the Sun, Venus and Mercury. "The reason why all these several heavens seem to the eye as one entire body is, because they are all clear and transparent like fine glass or crystal through which the sight doth easily

pierce, though there were never so many coats of such clear substance, covering one another like the scales of an onion, for so the heavens do cover and enclose one another, and every one is of an exceeding great thickness." As our author is nothing, if not accurate, he proceeds to give the thickness of these several heavens as follows:

"The Heaven of the Moon, 105,222 $\frac{2}{33}$ miles.
of Mercury, 253,372 $\frac{2}{3}$
Venus, 3,274,494 $\frac{6}{11}$
Sun, 343,996
Mars, 26,308,800
Jupiter, 1,899,654 $\frac{6}{11}$
Saturn, 19,604,454 $\frac{6}{11}$."

He further says, "The stars be of the same substance that the heavens are wherein they are placed, differing only from the same in thickness; they are bright and shining bodies, the thickest part of their heaven, apt both to receive and retain the light of the sun; and in like manner the galaxy is visible to the eye, by reason it is thicker than any other part of the heaven. These stars have no moving of themselves, but by reason of the manifold moving of the firmament wherein they are placed they seem to change their places: and whereas the planets do change their places now here, now there, that chanceth not of their own moving, but by the moving of the heavens wherein they are placed; for a star being round of shape hath no members meet to walk from one place to another."

Having thus disposed of the celestial sphere we turn to the four elements earth, air, fire and water: it will be remembered that fire comes next inside the heaven of the moon, and it is here defined as "most hot and dry, pure and subtle, and so clear as it doth not hinder our sight looking through the same to the stars: and it is turned about under the sphere of the moon like a celestial sphere. The air is divided into three regions, the highest of which being turned about by the fire is made hotter, wherein are bred lightnings, blazing stars and such like; the middle region is extremely cold *because* it is placed between two hot ones, and in it are bred frost, snow, ice and hail and such like; and lastly the lower region, which is hot by reflex of the sun, whose beams first striking the earth do rebound back again; and in this region are bred clouds, dews, rains and such like moderate watery impressions." The water is considered to be of itself round; and that this is so is proven by the familiar illustration of a ship sailing from port and losing sight of low objects, while elevated ones remain in sight; but it never seems

to occur to the author that by this the spherical shape of the globe may be proven.

The small globes used for purposes of instruction, having upon them different circles as the meridian, ecliptic, &c., next claim the attention. Then follow instructions for obtaining the sun's place in the ecliptic and thence his declination, with tables to facilitate the operation: the subject of eclipses is briefly touched upon, as is also that of the precession of the equinoxes and the need for a reformation in the calendar; the names of the principal stars are given with directions as to finding their right ascension and declination. The division of time is noticed and the different kinds of years are defined, and a reason assigned for the inequality of the days and nights, and rules given for "finding what planet reigneth at any hour of the day or night." Longitude and Latitude are defined as follows; "The longitude of the earth in general is that space or upper face of the earth, which extendeth from West to East and again from East to West; and the Latitude in general is that space which extendeth North and South even from one pole to the other." The prime meridian passes through the Azores, which are 5° to the Westward of the Fortunate (or Canary) Isles, where was the prime meridian of Ptolemy: this change was made "because, say the Cosmographers, the Mariner's Compass will never incline to the true North pole but when they sail either by the Isle St. Mary or St. Michael; affirming that in every other place the compass doth vary from the true North either by Northeasting or Northwesting." Next follows the method of obtaining the latitude by the meridian altitude of the sun, with the statement that the altitude must be measured at intervals and the highest altitude taken. The problem of determining the longitude is disposed of very briefly by directions for observing the beginning of an eclipse, the time to be compared with the computed time of such beginning at some other place. The germ of our modern method is found in the tenth chapter of this treatise, which is taken from Gemma Frisius; he says, in effect, "this is done by the help of some true watch or horologe, which is to be set to local time before leaving a place, and is to be compared with the local time at the place of your arrival; the difference of which times will be the difference of longitude. "This method," he further states, "is applicable only on land, as watches made of iron or steel will soon rust at sea: the twenty-four hour glass is therefore used at sea, to keep the local time of the port of departure." A further method of obtaining the longitude by Lunar distances, is also given: this was

liable to very great errors, owing not only to the imperfection of the Lunar tables but also to great lack of instruments of precision for measuring the distances.

Next follow directions for obtaining the distance between two places by taking the difference of latitude and difference of longitude: the latter being converted into *departure* by means of tables which give the length of a degree in every parallel of Latitude; and this departure used in the solution of the problem is reckoned on the Middle Latitude between the two places: nowhere, however, is anything said about the course, nor is any explanation of the problem given. With a few sections devoted to the seasons and their characteristics, and a short article on the winds and their names as derived from the different points of the mariner's compass, the book ends: these being the closing words: "I heartily pray all those that shall vouchsafe to read this my treatise of the sphere, to take my labor therein bestowed in good part, and where any fault is, friendly to correct the same without any scorn or disdain."

The next treatise is upon "the use of the globes": these were the invention of Mercator, and were used for the solution of spherical triangles, especially in those cases involved in Navigation: the celestial globe had the horizon and meridian, declination circles, the equinoctial and ecliptic; as also an hour wheel at the pole, by means of which the hour angle of a body was readily determined. As a proof of the old saying that "History repeats itself" and of that equivalent aphorism of Solomon that "there is nothing new under the sun," I would here state that within the last six months there have been put forth the drawings of an instrument called the Automatic Navigator, which in all its essential parts is but a reproduction of Mercator's celestial globe, the very existence of which was probably entirely unknown to the inventor of this latest improvement. Among the many problems, rules for the solution of which are given, and which are thus solved mechanically may be mentioned the finding of the latitude; first, by the meridian altitude of any heavenly body (two methods); and second, by altitudes of two different bodies at the same time; also the finding of the longitude by means of a lunar distance. Following this is a description of a large terrestrial globe then lately put forth, being an improvement upon the original one of Mercator, with a brief account of the voyages of Drake and Cavendish, whose tracks in their then recent voyages of circumnavigation are put down upon this globe.

Next follows a description of the map or chart of *Plancius*, which

had but just been published. In this map (it was not a projection), the meridians and parallels were at right angles, and the degrees of latitude were of the same length from the equator to the pole. Tables were annexed showing the value of a degree of longitude in miles at each latitude, but the fact that these parallels were expanded in the ratio of the secant of the latitude, is entirely lost sight of, although Mercator's chart had then been before the world for a quarter of a century. In another place commenting upon this last fact, the author says "that *Cogniet* hopeth to find out some more perfect rule for making charts when time shall serve: in the meantime *Mercator* hath made the spaces of the parallels of latitude to be wider every one from the other, by what rule I know not, unless by such a table as my friend Master Wright of Caius College, Cambridge, hath sent me"; which table is Wright's Table of Meridional Parts, computed on the supposition that the earth is a sphere; and it is to Wright rather than to Mercator himself, that we are indebted for the elucidation and demonstration of the true principles involved in the construction of Mercator's Chart. But to return to the chart of Plancius; from this we learn that Symmes' Hole is not by any means a modern idea; for Plancius tells us that "there are three islands next the pole, between which the North ocean sea rushes with swift stream and is continually carried under the North pole and there is swallowed up by the bowels of the earth; but," says Blundevile, "I marvel how any ship durst enter through these straits to discover the North sides of any of those islands, and how and where it came out again." The magnetic pole is placed in longitude 0° (corresponding to our longitude 25° W.) in latitude 75° North. Then follows a description of the various countries of the world, with an account of some of their remarkable curiosities. Next follows an article devoted to the South circumpolar stars with a description of the Southern cross, the star in the foot of which is stated to be thirty degrees distant from the South pole, so that when the meridian altitude of the star is taken, by subtracting thirty degrees therefrom, the latitude is at once given. The method of determining the distance between two places on the map, is given; and our author closes his review of Plancius' work with these feeling remarks; "Truly I must needs confess that it is not so easy to make a scale for a map drawn *in plano*, as for that which is drawn upon a round body or globe: and therefore it is no marvel that the scale of maps drawn *in plano* do not always show the true distance of places; which true distance is to be found by rules which depend upon the knowledge of the quantity of the angles and sides of spherical triangles, which

kind of working is indeed *more troublesome and tedious, than ready or pleasant.*"

We next have an elaborate account of "Blagrave's Astrolabe or Mathematical Jewel." This astrolabe was not of the kind generally used for taking observations at sea, though it might so be; it was essentially a planisphere, having upon its face or *Mater*, the various meridians, parallels &c., projected stereographically; upon this, and concentric with it, was a movable plate styled the *rete*, having altitude and azimuth circles projected upon it, in the same manner as were the others upon the *Mater;* Chauvenet's great circle protractor is constructed upon the same general plan; and is used in the same general way as was the astrolabe of Blagrave. Upon the face of the rete was also an oval figure containing the signs of the zodiac in order, and also the names of seventy-one fixed stars, for convenience in using the instrustrument in finding the places of those heavenly bodies. Upon the back of the planisphere, was a large circle graduated to degrees and minutes, with a diopter or ruler working upon its central pin; this ruler had a projection at either end, perpendicular to the plane of the instrument; these were each pierced with two holes which served to direct the line of sight of the diopter to the sun or other heavenly body, while the extremity reaching the graduated arc showed the altitude. The author speaks of the book of instructions concerning this astrolabe, written by Blagrave, implying that the theory of the instrument is therein discussed; he confines himself to simple rules for its manipulation, without concerning himself as to the theoretical part.

With these preparations, from the Arithmetic at the beginning of the book to the account of the astrolabe just noticed, the author now takes the student into his "New and Necessary Treatise of Navigation, containing all the chiefest principles of that art. Lately collected out of the best Modern Writers thereof, by M. Blundevile, and by him reduced into such a plain and orderly form of teaching, as every man of a mean capacity may easily understand the same." The title page is embellished with the picture of a ship, with this motto "They that go down to the sea in ships, and occupy their business in great waters, these men see the works of the Lord, and His wonders in the deep."

Navigation is defined to be "an art which teacheth by true and infallible rules how to govern and direct a ship from one port to another safely, rightly and in shortest time. I say here safely, so far as it lieth in man's power to perform. And in saying rightly, I mean not by a right line, but by the shortest and most commodious way that

may be found; and by saying in shortest time, I mean thereby according as the ship is good of sail and as both wind and tide shall serve." The instruments which every skilful seaman should possess before undertaking a long voyage, are said to be "a perfect Calendar or Ephemerides; the Mariners Ring or Astrolabe; the Cross-staff; the two Globes, celestial and terrestrial; an universal horologe, to know the hour of the day in every latitude; a Nocturnlabe, to know the hour of the night; the Mariner's Compass; and lastly, the Mariner's Card or Chart. "But" says Blundevile "all these instruments serve to little purpose unless you know also the North star with his guards, and divers other stars with their latitude, longitude and greatness, to know thereby the latitude of any place and the hour of the night; also the course of the sun and his declination; and finally you must know the course of the moon, whereon dependeth the knowledge of the tides in all places." With these as his subjects, he proceeds to discourse upon them in the order just rehearsed. The perfect Calendar or Ephemerides to which he refers was by no means the article known to us as the Nautical Almanac: it contained merely the place of the sun, moon and planets in the signs of the zodiac and their place in those signs, for every day in the year: the declination of the bodies was otherwise obtained. In his remarks upon the calendar, our author directs us how to find the golden number, the epact, the full and change of the moon and the various fast and feast days throughout the year. We here find in the chapter devoted to the Epact, a paragraph which shows the probable origin of our modern term "*thumb-rule.*" As I have never before met with any plausible theory as to the origin of this phrase, I have here transcribed a portion of

"CHAPTER III.

How to know the Epact by the Mariner's Rule *upon your thumb.*

First, you must suppose the inside of your left thumb to be divided into three spaces, and the nethermost space to contain ten, the middle space twenty, and the highest space towards your thumb's end to contain thirty: and knowing first the golden number, begin to tell the same at the nether space, saying there one, at the middle space two, at the third space three, then begin again at the lowest space and then say four, and so continue your account still after that manner, until you have the full sum of the golden number, and mark upon what space it falleth, for the golden number added to the number of that space doth show the Epact."

Cogniet's cross staff consisted of a piece of hard wood, three quarters of an inch square and four feet long with three transoms or cross pieces of different lengths sliding upon it; the first of these was twelve inches, the second six, and the third three inches, in length; the long piece or staff was graduated to degrees by means of a simple triangle; the altitude was taken by placing the end of the staff at the eye and then moving the transom until the sun was visible at the upper extremity thereof and the horizon at the lower; the longest transom was used for altitudes exceeding thirty degrees, the second for altitudes between thirty degrees and ten degrees, and the shortest one for altitudes less than this. This instrument also appeared in another form, known as *Hood's* cross staff; in this there were two pieces of wood three quarters of an inch square, and about a yard in length: these were set at right angles to each other in a metal socket, in which each one moved readily, being retained at any desired point by a set screw. The horizontal part was called the yard, the vertical one, the transom; each was graduated to degrees and minutes, the least count being ten minutes; the transom was marked from 0° to 45°, and the yard from 45° to 90°. This graduation was made in the ratio of the tangent of the angle from 0° to 45° and of the cotangent from 45° to 90°; although Blundevile says nothing about it; from his text it would readily be inferred that the graduations were equal, which of course would have given extremely incorrect results. At the zero mark of the transom was a metal plate, flush with the graduated surface and projecting from it about three quarters of an inch; in this plate was a notch, the bottom of the notch being in line with the zero of the scale. This instrument was made ready for use by inserting both portions into the socket, the 45° marks being together; the altitude of the sun was taken by holding the yard as nearly horizontal as possible (decidedly a difficult matter to accomplish on board ship) and observing where the shadow of the vane on the transom struck the yard, and then moving either the yard or transom in the socket utnil the shadow struck the 90° mark on the yard; the place of the socket was the reading of the instrument for altitude. In taking the altitude of a star the 90° mark was placed at the eye the instrument being "stayed upon the upper bone of the cheek", and when the line of sight passed through the notch of the vane and the star, the socket was clamped and the reading taken; lunar and stellar distances were measured in a similar manner. In its original and more common form the cross staff was like *Cogniet's*, heretofore described, with however but *one* transom instead of three.

The ordinary Astrolabe or Mariner's Ring was a metallic ring about

seven or eight inches in its exterior diameter, and about half an inch wide and of different thicknesses, according to the fancy of the maker. It was considered desirable to have the whole instrument as heavy as practicable, in order that it might readily retain its proper position. This ring had two perpendicular diameters of metal, at the extremity of one of which was a swivel, by means of which the instrument was suspended when in use; one quadrant was graduated to degrees and minutes, the least count being ten minutes. A diopter, reaching from limb to limb and turning upon a pivot in the centre, was furnished at each extremity with a square plate perpendicular to the plane of the instrument; these plates were each pierced with two holes, the smaller for use in observing the sun, the larger for the stars and moon. The instrument was suspended from the fore-finger or thumb of the right hand, while the left hand directed the line of sight through the diopter to the body whose altitude was desired, the altitude being read off the graduated arc.

The division of the Compass Card into thirty-two points is then explained, with the manner of attaching the card or fly to the needle or wires; which are figured as of elliptical shape, the major axis being prolonged to make the North and South poles: the method of imparting the virtue of the lodestone to the iron needle is also mentioned. The further statement is made that "it is well known by good experience that the North point of the compass declines always from the true North, either to the East or West, more or less, according to the latitude of the place wherein you are, unless you be right under the meridian of the Azores. And therefore most men in these parts of the world do use to set the North point of the wires not right under the flower de luce (or North point of the card) but rather somewhat inclining toward the East, half a point or thereabouts to avoid the Northeasting and Northwesting of the compass." As an additional illustration or proof of Solomon's saying as to the want of novelty of anything under the sun, I would here state that within the last year there has been patented in this country an instrument called a Variation Compass, the principle involved in its construction and its method of manipulation being precisely the same as that here noted by Blundevile; viz., the alteration of the card and needle according to the Variation. Assuming the line of no variation as being coincident with the Meridian of the Azores (or longitude 0°), Mercator placed the magnetic pole in longitude 180°, and in latitude 73° 30′ North; and he thought that at this pole was a "great rock of adamant whereunto all lesser rocks or needles touched with the lodestone do incline as to their chief fountain;" con-

cerning which Blundevile declares that "he rather believes with Robert Norman, that the properties of the loadstone are secret virtues given of God to that stone for man's necessary use and behoof, of which secret virtues no man is able to show the true cause." Cogniet's proof that Easterly variation is found in the hemisphere from longitude 0° to 180° East, and Westerly variation in the other hemisphere, is shown; as also his statement that of two places having the same longitude that one will have the greater variation, which is the nearer to the pole. Instructions for finding the variation are then given; the first method was by observing the bearing of the sun at his rising and again at his setting, when half the difference of these two bearings in points from the Meridian would give the variation; the second method is a modification of the first, the bearing of the sun being taken when at the same altitude on both sides of the Meridian, the variation being found in the same way; a third method was to note the sun's bearing at the instant of taking the Meridian altitude, and the fourth method was by observing the bearing of the North star.

Next follow directions for constructing a chart by the old method which was followed by Plancius: but the author prefers Mercator's Projection as being more suited to the uses of the mariner. For this purpose he gives Wright's Table of Augmented Latitudes with full instructions as to the mechanical portion of the operation, including the insertion of compass cards in convenient spots. Although the text discusses the question of the loxodromic curve and shows that it must necessarily be a spiral, yet no where is it noted that on Mercator's chart this curve is projected as a right line; although the fact is stated that the direction of the right line between two places will be the course between them. The compass course was obtained not by parallel rulers, which seem to have been then unknown, but by a system of guessing, using a pair of dividers as an assistance thereto: the distance was to be measured at the side of the chart.

The dead reckoning, in contradistinction to the reckoning by observation, did not exist; they were not independent of each other: nor is there any mention of the log or of any other appliance for measuring the speed of the ship at any time. When sailing upon a meridian, the distance made good was known by the change in latitude, sixty miles, or seventeen and a half Spanish leagues, in which distances were generally reckoned, being allowed to a degree: the means of determining the distance when sailing in any other direction than due North or South had but recently been published by Cogniet. His method was

briefly as follows: "if in sailing to the Northward or Southward the course declined one point or rhumb from the meridian and the ship sailed so far as to change the altitude of the pole one degree, then the distance was seventeen and five-sixths Spanish leagues"; and a table is given containing the distances in leagues necessary to be traversed to change the latitude one degree on the remaining courses between the cardinal points. This method of reckoning was of course good, only when the ship sailed on one course from latitude to latitude; but if there were any shift of wind necessitating a change of course "the pilot was by skilful conjecture either to add to or to subtract from this distance as such should require." In like manner the change of longitude was determined, and a table was given for this purpose, showing the change of longitude for a change of one degree in latitude when sailing upon a given course or rhumb: this change was given in leagues and also in degrees and minutes of the equator: this was to be used in all latitudes which was of course greatly incorrect, for the distance given in this table was the *departure*: although the principle of changing *departure* into *difference of longitude* was known, as we shall presently see, yet the idea of applying it in this particular case, seems to have been entirely unknown; at least it is not mentioned in the text: in the example given by the author, the error amounts to about four degrees of longitude in thirty. That this principle was known is seen from the next chapter, in which we are told "How to account the leagues in sailing East or West without changing the latitude." It is here stated that "in sailing thus, most men think it impossible to make any true account of the leagues, but only by conjecture: for remedy whereof Cogniet hath invented a rule most certain:" which was briefly this: "Knowing the difference of time between two places in the same latitude, this difference was to be multiplied by the number of leagues which were equal to fifteen degrees or one hour, in that latitude:" this number was tabulated for all latitudes from 0° to 90° and was practically the length of a degree of longitude in every parallel of latitude. The difference of time between the two ports was to be obtained as follows: a large sand glass made to run twenty-four hours was hung in gimbals: this was set running at noon by the sun on the day of leaving port: it was to be carefully turned every twenty-four hours and on arriving at the port of destination the time at which the glass ran out was to be carefully noted either by the horologe or universal dial, or obtained from the celestial globe or from Blagrave's planisphere, first obtaining the sun's altitude with the astrolabe: the difference between this time and the local noon

gave the difference of longitude of the two places in hours, which was reduced to distance as above stated.

Next follow detailed directions for finding the North star by means of the pointers or *guards* as they were called, and also for determining the latitude and the local time by observations of this star. To effect this there was given a table showing the degrees and minutes to be added to or subtracted from the altitude of *Polaris* according to the compass bearing of the pointers from the star; this correction was given for the four cardinal and four intercardinal points. To enable this correction to be found more accurately, an instrument called the Rectifier of the North Star was devised: this was the invention of Cogniet so often quoted in the text and was quite an elaborate affair: under ordinary circumstances it might produce tolerably accurate results. It consisted essentially of a compass card containing at each point the degrees and quarters of a degree to be applied to the altitude of the star according to the bearing of the pointers: a ruler turned upon a hollow spindle in the centre, through which the line of sight passed. When in use, the instrument was raised in front of the face by means of the handle (which was situated at the south point) until the star was visible through the central spindle: the ruler was then moved until the nearest pointer could be seen in line with it and the correction was read off the arc where the ruler intersected it. Directions are also given for using any other star than the nearest pointer, provided the difference of right ascensions was known. This instrument was also used as a Nocturnlabe or determiner of time at night: the inner circle of the compass card was divided into three hundred and sixty five equal parts, which were named and numbered according to the number of days in each month, the days upon which the star crossed the meridian at noon and midnight being placed opposite the North and South points respectively: a small circle divided into twenty-four equal parts or hours moved also upon the central pivot, and the twelve hour mark was placed opposite the day of the month before using the instrument: the reading of the point at which the ruler before mentioned cut the hour circle gave the hour of the night. Provided that the North and South line could be held in the plane of the meridian, this instrument would give very good results. The concluding chapters of the work are devoted to the subject of tides and the finding of the time of high water.

From this brief glance, we see that the mariner of three centuries ago was able to obtain results, which only by a very liberal stretch of the term could be called approximative. With the instruments at his disposal,

it could not have been possible to obtain the altitude of the sun within twenty minutes: to say nothing of the probable error of the declination owing to want of proper tables, there were no corrections made for semi-diameter, dip or refraction, and hence the latitude could not have been reliably determined within thirty minutes; probably if the result came within forty or forty-five minutes of the true one, it would be doing very well. As upon the determination of the latitude rested, as we have seen, the subsequent approximation to the distance and difference of longitude made good, it follows that these latter results must have been very far from the truth. And yet, before the close of the sixteenth century, even with such inferior means of determining the ship's position, the great voyages of discovery had been made. Prince Henry the Navigator had largely increased the existing knowledge of the west coast of Africa; Vasco de Gama had rounded the Cape of Good Hope and the African continent had been circumnavigated; Columbus had brought to light the New World; Cabot and a host of others had followed in his foot steps; Balboa had crossed the Isthmus of Panama and discovered the Pacific Ocean; Magalhaens had discovered the strait that still bears his name and sailing through it had entered the Pacific Ocean; stretching boldly across which, he reached the Philippine Islands, his vessel being the first to accomplish the circumnavigation of the globe.